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Sleeping Tongue Posture and Its Relationship to Craniofacial Morphology

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Sleeping Tongue Posture and Its Relationship to Craniofacial Morphology

By

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A thesis submitted in partial satisfaction of
the requirements for the degree of
Master of Science in Orthodontics and Dentofacial Orthopedics

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Each person whose signature appears below certifies that this thesis in his opinion is adequate, in scope and quality, as a thesis for the degree Master of Science.

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ABBREVIATIONS

TPI	Tongue Posture Index
A-P	Anteroposterior
CBCT	Cone-beam Computed Tomography
ICC	Intra-class correlation
FMA	Mandibular Plane Angle

ABSTRACT OF THE THESIS

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Master of Science, Graduate Program in Orthodontics and Dentofacial Orthopedics
Loma Linda University, September 2011
Dr. Joseph Caruso, Chairman

Introduction: There exists good consensus in the literature supporting the notion that resting tongue posture is an important factor in dental arch development and maintenance as well as airway control. What has yet to be quantitatively measured is the duration of time that a subconscious, resting tongue posture is maintained and whether such posture differs among various craniofacial morphologies. Quantifiable measurements might allow for prediction of tongue-posture-related problems specific to certain facial types.

Purpose: The objective of this study was to record sleeping tongue posture over time in 27 subjects and to compare findings with craniofacial morphology determined by cephalometric and model analysis.

Methods: A sample of 27 subjects (11 female, 16 male) slept for three nights each while wearing an intraoral, tongue-posture-monitoring device. Tongue posture indices (TPI) were calculated for each night and compared with vertical and transverse skeletal measurements taken from a lateral cephalograph and plaster study models.

Results: Nonparametric correlations demonstrated that average TPI is significantly and inversely correlated with palatal height, ratio of palatal height/palatal width, and lower face height (p < .002, .001, 028 respectively). Independent samples median tests showed that TPI was significantly lower for subjects that snore, breathe through their mouth and nose, and sleep on their back (p < .037, .057, .096 respectively).

Conclusions: Variability in sleeping tongue posture exists between people of differing facial morphologies. Sleeping tongue posture also appears to vary depending on sleeping position, breathing modality, and tendency to snore.

CHAPTER ONE

INTRODUCTION

Statement of the Problem

It has been shown in the literature that masticatory muscle *function* is closely related to craniofacial morphology.[1-5] What has yet to be shown is the correlation of facial type with *resting* muscle posture, specifically tongue posture. There is no established "baseline" commonality for resting position of the tongue, or whether a "proper" tongue posture exists that will aid in dental arch equilibrium beyond that which has been proposed theoretically or anecdotally. Why is this important? The tongue has the potential of acting as a functional appliance by opening the bite and encouraging differential eruption. It can upset the delicate balance that holds the teeth in their proper position, and potentially lead to crossbite, open bite, a class II division I malocclusion or any other number of untoward orthodontic or respiratory effects.[6,7] Recent research has also shown that tongue posture may play a vital role in airway control.[8,9]

Hypothesis

The objective of this study is to quantitatively record duration of resting tongue posture during sleep and compare it with craniofacial morphology, the null hypothesis being that there is no difference in sleeping tongue posture between subjects with varying measurements of vertical, transverse, and A-P dimension. The alternative hypothesis is that there is a significant difference in tongue posture depending on these measurements.

CHAPTER TWO

REVIEW OF THE LITERATURE

Equilibrium

In orthodontics, and dentistry in general, much attention is given to tooth position so as to allow the greatest possible number of contacts when the upper and lower dentition come into contact. This concept of "stable occlusion" is one of the primary objectives of orthodontic treatment. However, maintenance of an already stable occlusal relationship or retention of an orthodontically-created occlusion is dependent upon an equilibrium.

The "equilibrium theory of tooth position" has been explored and debated to great extent already, the general consensus being that many factors contribute surrounding forces on a tooth, the sum of which equals zero in a stable dentition. All possible factors must be considered, i.e. bone, PDL, adjacent teeth, the tongue and buccal musculature, the opposing dentition, as well as foreign objects such as fingers, pencils, lip, etc. The degree to which muscle tissue influences the net overall forces on the dentition remains unclear. Few can argue that soft tissue plays little or no role in tooth equilibrium. One need only observe the flared upper incisors of a lip biter, or hear reports of lower incisor soreness after initial bracket placement without an archwire.

Weinstein et al demonstrated through a series of experiments that tooth movement did occur when tooth size was asymmetrically increased bucco-lingually, upsetting the soft tissue balance. A 2-mm gold onlay was placed on either the buccal or lingual surface of selected teeth in vivo, thereby increasing the size of the teeth and disrupting the established equilibrium position. Tooth movement was observed as the teeth found a new position of zero-net force. It was evident that for this to occur, continuous force was required to obtain this new position of equilibrium; intermittent force was not sufficient. Weinstein also provided convincing evidence that more than one position of equilibrium for a tooth may exist.[10] This seems logical. Otherwise, how would successful orthodontic treatment be possible?

Proffit conducted studies on tongue and lip pressures in Australian Aborigines and North American Whites. Using pressure sensors he recorded the pressures exerted by the tongue on the palate and lingual surfaces of maxillary and mandibular teeth as well as the force exerted by the lips and buccal musculature on the buccal surfaces of the dentition. The results were not as expected. The Australian Aborigines, with on average much broader arches and more pronounced prognathism, had lower "at-rest" pressure readings from the tongue when compared with North American whites. The lip pressure readings were nearly identical. Profitt concluded from his study and others that, "it appears that the form of the dental arch dictates the functional pattern of tongue and lips to a much greater extent than function alters form."[11]

But how does one explain the myriad cases of mouth breathing adolescents whose upper arches are collapsed and exhibit posterior crossbite? Proffit concedes that "to the extent that the form of the dental arches is influenced by the musculature, resting pressures and the resting posture of tongue and lips seem more important than pressures during swallowing or speech." Indeed, Proffit claims that in the case of open bite, many factors are likely at work. "Resting tongue and lip pressures might logically affect the vertical position of teeth just as they affect positioning in other planes of space. There is no reason to attach special importance to tongue pressures during swallowing except that an unusual tongue position in swallowing may also indicate an altered resting posture."[11] Harvold et al experimented with lumps of plastic placed against the palates of monkeys to displace the tongue from its normal position. The immediate effect was insignificant but the long term consequences included maxillary arches that were considerably reduced in width.[12]

Resting Tongue Posture

While it seems widely agreed upon that resting tongue posture plays a primary role in maintenance of dental equilibrium, there is disagreement as to the exact position of the tongue with regard to resting tongue posture. Carlson et al. showed through electromyography that masticatory muscle activity was greater with the tongue positioned against the palate than with the tongue postured in the floor of the mouth. Why is this finding important? According to Carlson, "Despite the current discussions concerning the lack of a relationship between muscle activity and pain reports in controlled experiments, finding a position of relaxation for the tongue and facial muscles is often identified as an important step in the clinical management of orofacial pain." So from an orofacial pain standpoint, less overall muscle activation around the masticatory complex tends to help those dealing with myofacial pain.[13]

Carlson also proposes that maintaining pressure of the tongue against the roof of the mouth would require recruitment of muscle fibers and such muscle activity would be inconsistent with the term “rest.” Furthermore, in an upright position one would need to overcome the force of gravity to maintain this posture which over a period of time could result in muscle fatigue and discomfort because of the effort required to maintain a “relaxed” position.[13]

In using a special technique for taking tongue impressions in “rest” position, it has been this author’s observation that in many people there likely exists an airspace between the center of the tongue and the palate. As the tongue creates a seal with the tip of the tongue contacting near the incisive papilla, the lateral borders along the palatal surfaces of the maxillary dentition, and the posterior portion of the tongue contacting the soft palate, this airspace creates a vacuum of negative pressure which aids in maintenance of tongue posture by relieving otherwise needed muscle fibers. This hypothesis remains unproven but may merit greater scrutiny through further research.

Takahashi et al. performed essentially the same study as Carlson but with greater specificity on tongue position. They used surface EMG to monitor the masseter, anterior temporalis, and suprahyoid muscles while having the subject hold their tongue in three positions: rest, superior and anterior, corresponding to sensors placed in the depth of the palate and on the lingual of lower incisors. Takahashi found that masticatory muscle activation with the tongue in “rest” position was much less than with the tongue in “superior” or “anterior” poistion.[14] What Takahashi failed to establish is where “rest” position is. The subjects were presumably instructed to position their tongue in the most comfortable position to find "rest" but there was no attempt to discover where that position was in each subject or if it was common among all subjects.

Takahashi et al also studied tongue pressure as it relates to changes in breathing mode and body position and successfully demonstrated that changes in body position significantly affected the maximum tongue pressure during oral breathing. Also, the activity of the genioglossus muscle changed significantly with different breathing modes and body position.[15] That is to say that tongue pressure against the lower incisors increased during oral respiration in both upright and supine body positions. Recordings taken during nasal breathing showed much lower force values against the lower incisors in both body positions indicating that tongue pressure was directed elsewhere, presumably the palate.

Craniofacial Morphology

Some newer studies have looked into the relationship of facial type with the surrounding soft tissue. As recent as April 2011 Jang et al. published a study in the American Journal of Orthodontics and Dentofacial Orthopedics that looked at the association between the lingual frenulum and craniofacial morphology. The study concluded that patients diagnosed with ankyloglossia might have a tendency toward skeletal Class III malocclusion.[16] Grauer et al. researched airway volume using CBCT and related it to facial type. They found that among patients with differing anteroposterior jaw relationships, airway volume and shape also differed. However, when it came to patients with differing vertical jaw relationships, only airway shape was significantly different, not volume.[17]

Modern Devices

Intraoral sensors have been used most frequently to study tongue posture in general but more recently other modalities have been utilized. Deglutition patterns have been observed using real-time magnetic resonance imaging.[18,19] In children exhibiting posterior crossbite, ultrasound technology has been used to visualize the shape of the tongue at rest.[20] While useful for studying short-term tongue patterns, these methods do not give longitudinal data in a subconscious environment.

By its nature, posture is long term and therefore accurate measurements have been difficult to achieve.[21] Also, whenever instrumentation is introduced into the mouth, there is the possibility that the activity being studied will be altered by the presence of the recording instrument.[22] It would therefore be ideal to monitor tongue posture with the subject in a subconscious state, virtually unaware of the recording device, so this study was designed to record nocturnal tongue posture, while the subject is sleeping.

CHAPTER THREE

METHODS AND MATERIALS

The study was reviewed and approved by the Institutional Review Board of Loma Linda University. Twenty-seven adult subjects were selected from a pool of dental students, residents, and spouses of students. Candidates were screened using a questionnaire that included the following questions:

1. Do you breath primarily through your mouth or nose or mixed?
2. Have you been diagnosed with nasal obstruction? What specifically?
3. Do you have a history of chronic sinus infections?
4. Do you currently have a cold or sore throat?
5. Do you have any allergies that affect your breathing?
6. Do you snore or breathe heavily while sleeping?
7. Are you consistently sleepy during the day?
8. Have you been diagnosed with obstructive sleep apnea?
9. Are you a restless sleeper?
10. Do you wake with a dry or bad taste in your mouth?
11. Do you know your preferred sleeping position?
12. Have you had your tonsils and/or adenoids removed?
13. Do you grind or clench your teeth at night?

14. Have you had any orthodontic treatment in the past?

15. Did your orthodontic treatment include palatal expansion?

16. Do you have ankyloglossia (tongue tied)?

Subjects with respiratory problems including nasal obstruction, seasonal allergy symptoms, recurring sinus infections, frequent/recurrent sore throat[23] were excluded from consideration for the study. Subjects with ankyloglossia were also excluded from the study. Of the 27 subjects that were selected 11 were female and 16 were male, with ages ranging from 23 to 38. Proper informed consent was obtained from each subject.

A custom-made mouthpiece was fabricated for each subject with the capability to electronically record tongue up/down position over time, by way of a sensor placed in the palate that records tongue position at a rate of one sample per second for a maximum of eight hours. The sensor used was an infrared emitter and phototransistor detector, which are mounted side-by-side with an integral barrier to minimize crosstalk. The original design of this generic sensor was to facilitate detection of reflective objects at very short distances; in this case, the tongue. Sensor placement was standardized to a location slightly lateral to the mid palatal raphe at a depth tangent to a line connecting the palatal cusps of the first premolars. The mouthpiece was connected to a small, portable flash drive by a wire that exits the mouth between the lips (Figure 1).

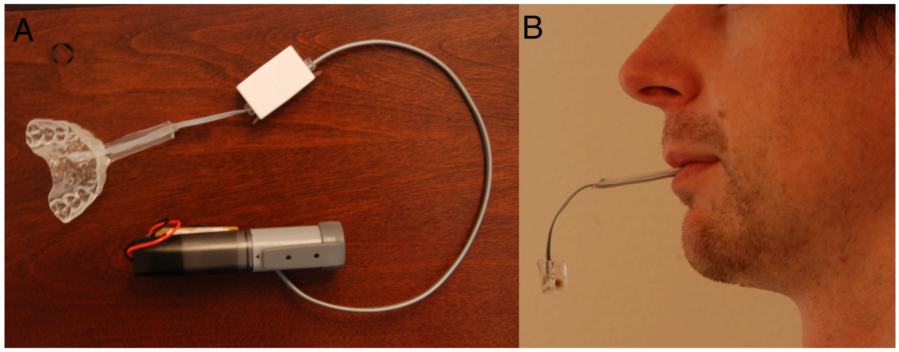


Figure 1. **A**: Mouthpiece connected to memory device **B**: Subject with mouthpiece inserted

Each subject wore the device for the duration of sleep for three nights. Instructions were given to each subject upon delivery of the device which included following a uniform protocol for attachment of the mouthpiece to the flash drive each night. Subjects were also asked to do a calibration exercise before going to sleep in which each person raised and lowered their tongue for ten seconds at a time, repeated three times (Figure 2). This was to ensure proper functionality of the sensor, flash drive, and connections. Subjects were given a small notebook that served as a sleep journal wherein they could record time of retirement, time of arousal the next morning, and any period of wakefulness during the night that exceeded 30 minutes.

The data was collected and the graphs analyzed. A tongue posture index (TPI) was calculated for each night of recording by taking the number of seconds that a tongue up posture was demonstrated and dividing that number by the total number of seconds asleep. This was done using tongue posture readings starting approximately 30 minutes after the subject's self-reported bed time and ending approximately 30 minutes before arousal in the morning. Care was taken to ensure that each subject provided at least five hours of usable data per night of sleep. Some sample graphs representing the various tongue postures observed are illustrated in figure 3.

Basic records of study models and a lateral cephalometric radiograph were taken. Cephalometric analysis was conducted by digitally tracing the lateral cephalograms using Quickceph Studio™. Angular measurements considered were: total face height (Na-Ba, Xi-PM), lower face height (Xi-PM, Xi-ANS), facial axis (Na-Ba, Pt-cGn), and FMA (FH-MP). These measurements represented the vertical component of each subject's facial morphology.

Transverse dimensions were evaluated using plaster casts of the upper arch of each subject. Palatal width was determined by measuring from the central pit of one upper first molar to the central pit of the contralateral first molar using a digital caliper with measurements being repeated three times and then averaged. Palatal height measurements were done in a similar manner to Sokucu et al. Models were trimmed until the distal contact points of the upper first molars were visible. The distance from the deepest part of the palate to a line connecting the right and left distolingual cusp tips was measured using a digital caliper [24], again repeated three times and averaged (Figure 4).

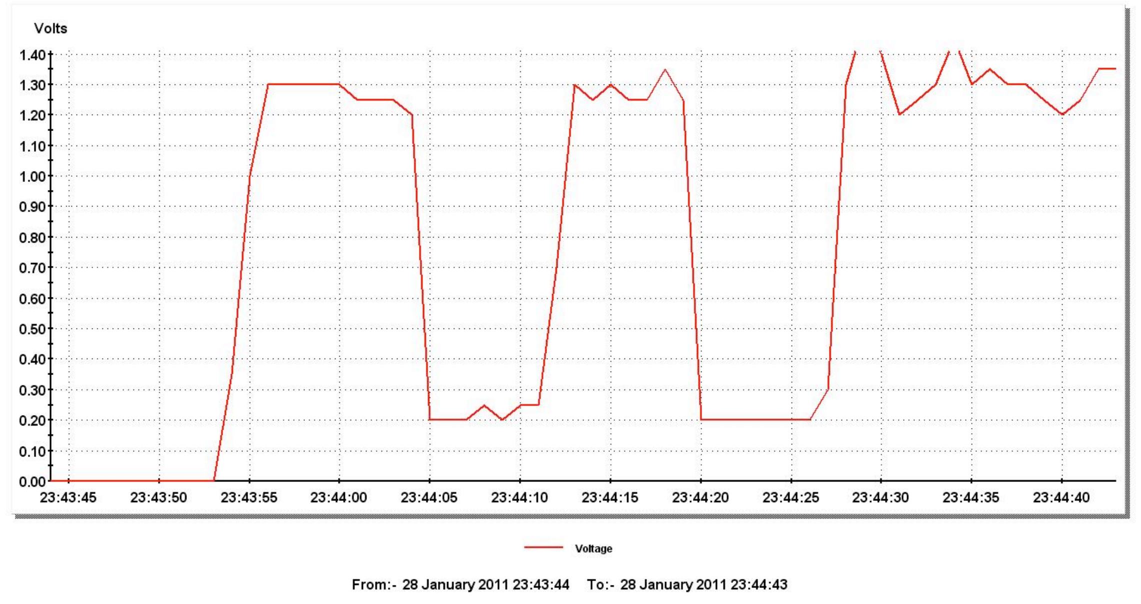


Figure 2: Graph (magnified) showing tongue calibration of one subject with volts on the y-axis and time on the x-axis. Tongue was placed in roof of mouth for approximately 10 seconds and then in floor of mouth for ten seconds, repeated three times.

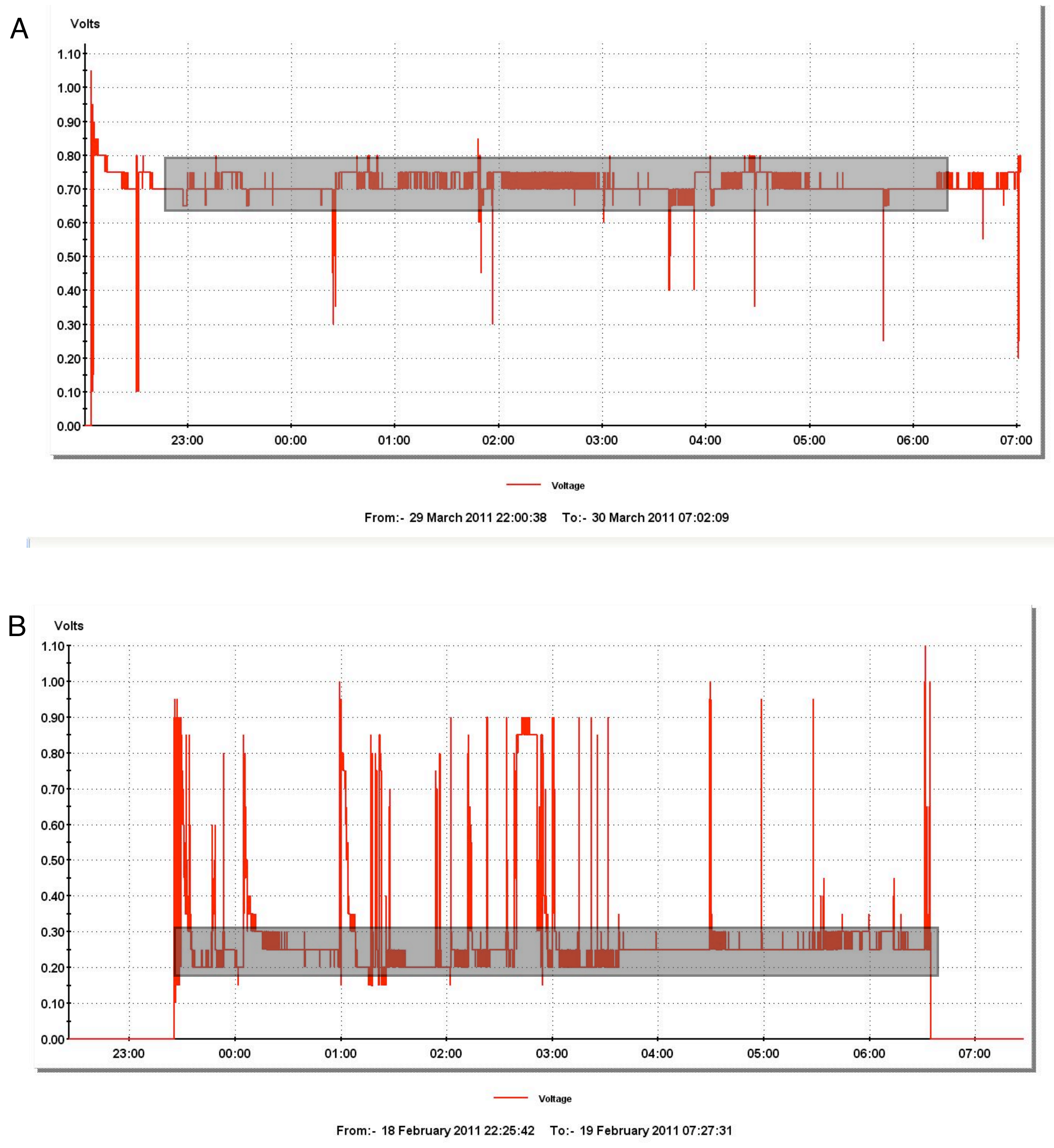


Figure 3. **A**: Graph representing a predominately "tongue up" posture with the tongue dropping down intermittently throughout the night. Tongue posture index = 0.998 **B**: Graph representing a predominately "tongue down" posture. Tongue posture index = 0.049

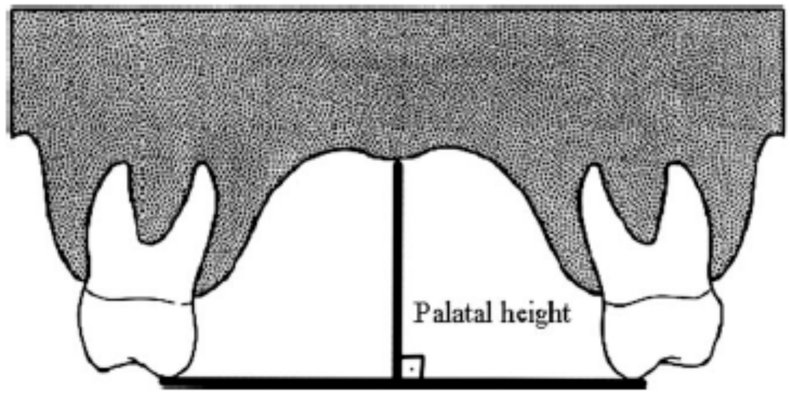


Figure 4: Method for measuring palatal height

Statistical Analysis

An independent samples median test was used to compare TPI with self-reported snoring, breathing modality, and sleeping position. Non-parametric correlation tests (Spearman's rho) were done to compare TPI with palatal height, palatal width, ratio of palatal height/palatal width, FMA, lower face height, facial axis, and total face height.

A logistic regression model was built to determine whether TPI could be predicted from a constellation of covariates that were measured.

CHAPTER FOUR

RESULTS

A summary of the collected data is presented in Table 1. The outcome measure of tongue posture index that was recorded had a negatively skewed distribution as is illustrated in Figure 5. Graphs of other independent variables recorded are also included.

The TPI value of each subject that was used for comparison with independent variables was an average of the three nights. The average individual range of TPI values for all 27 subjects was 0.141 demonstrating high reproducibility. The maximum individual range was 0.355 and the minimum 0.005 with eleven subjects having a range of less than 0.100. The Intraclass Correlation Coefficient (ICC) was calculated at 0.922. (Table 2)

Univariate testing with an independent samples median test showed that average TPI is significantly higher for those who reportedly did not snore when compared to those who did ($p = 0.037$)(Figure 6). The same type of test showed that those who reported both nasal and oral breathing tendencies (mixed) had considerably lower TPI on average when compared to those who reported only nasal breathing ($p = 0.057$)(Figure 7). And finally, average TPI appears to increase as sleeping position goes from the back towards the stomach. ($p = 0.096$)(Figure 8).

A Spearman's Rho correlation was conducted which demonstrated that average TPI is significantly and inversely correlated with palatal height, ratio of palatal height/palatal width, and lower face height (Table 3).

A logistic regression model was constructed using a combination of covariates, the most predictive being sleep position and palatal height (Table 4,5). First, average TPI was dichotomized into <0.75 or >0.75. This cutpoint was arbitrarily chosen given that it reflected the median TPI. Using the chosen predictors, approximately 83% (20/24) of the subjects studied were classified correctly into a TPI group. Specifically, if one sleeps on their side as opposed to their back they are 35 times more likely to have a TPI above 0.75. Also, for every millimeter increase in palatal height, one increases their odds of a high TPI. Due to the small sample size the confidence interval is very large (1.49 to 865.55).

Table 1: Summary of Findings

	Mean	Std. Deviation	Minimum	Maximum
TPI - 1	0.679	0.320	0.017	1.000
TPI - 2	0.697	0.321	0.024	0.997
TPI - 3	0.665	0.320	0.016	1.000
TPI - Mean	0.681	0.312	0.058	0.996
Palatal Height (mm)	19.77	2.60	15.87	25.66
Palatal Width (mm)	46.99	3.36	40.83	54.89
Ratio PH/PW	0.423	0.064	0.323	0.593
FMA (deg)	21.39	5.73	12.50	39.00
Lower Face Height (deg)	44.62	3.85	38.40	54.40
Total Face Height (deg)	56.10	5.31	48.20	68.10
Facial Axis (deg)	89.90	3.80	82.40	96.00

Table 2: Intraclass Correlation Coefficient

	Intraclass Correlation	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	0.922	0.860	0.961	36.471	26	52	.000
Average Measures	0.973	0.949	0.987	36.471	26	52	.000

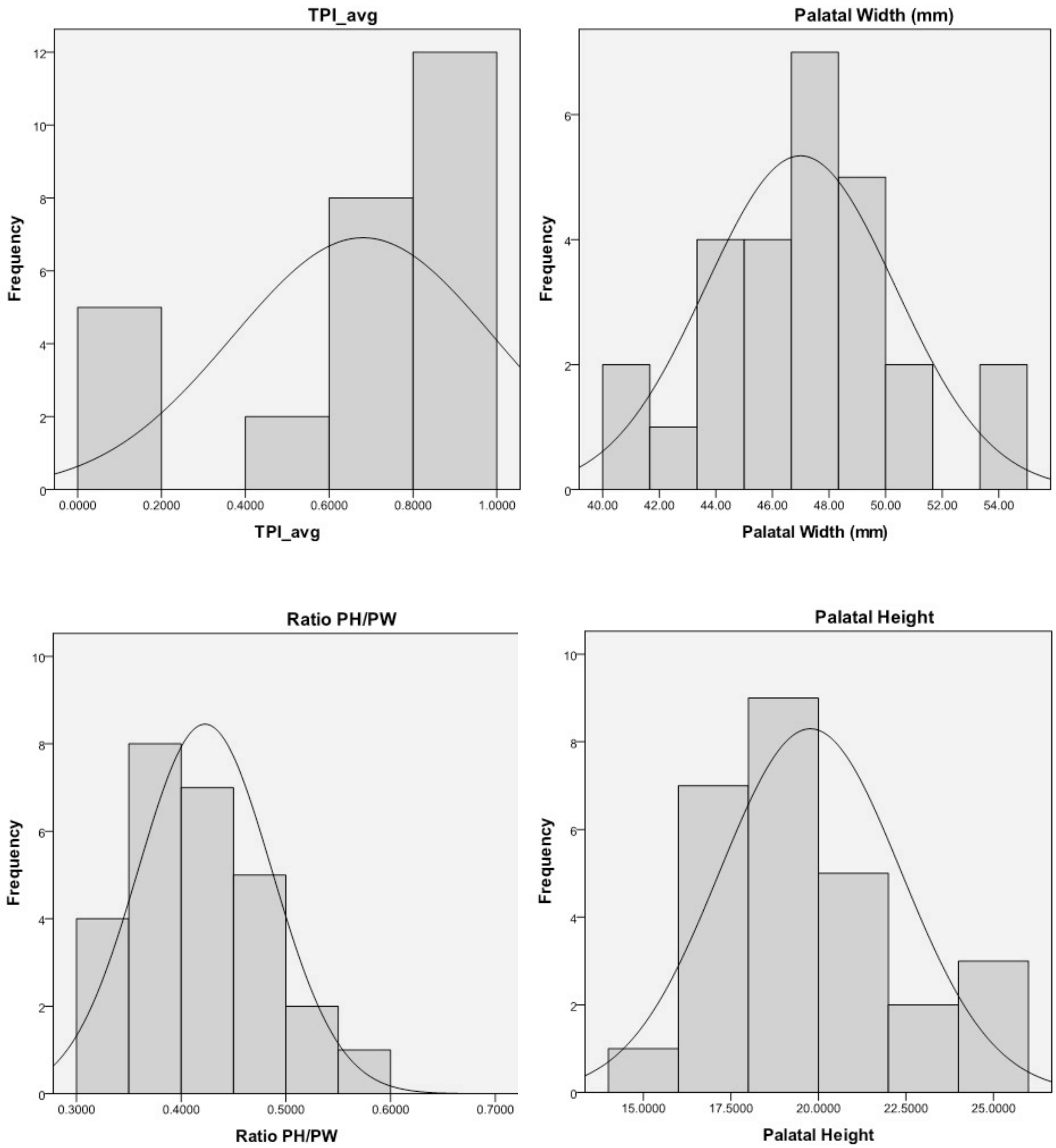


Figure 5: Graphic representation of collected data

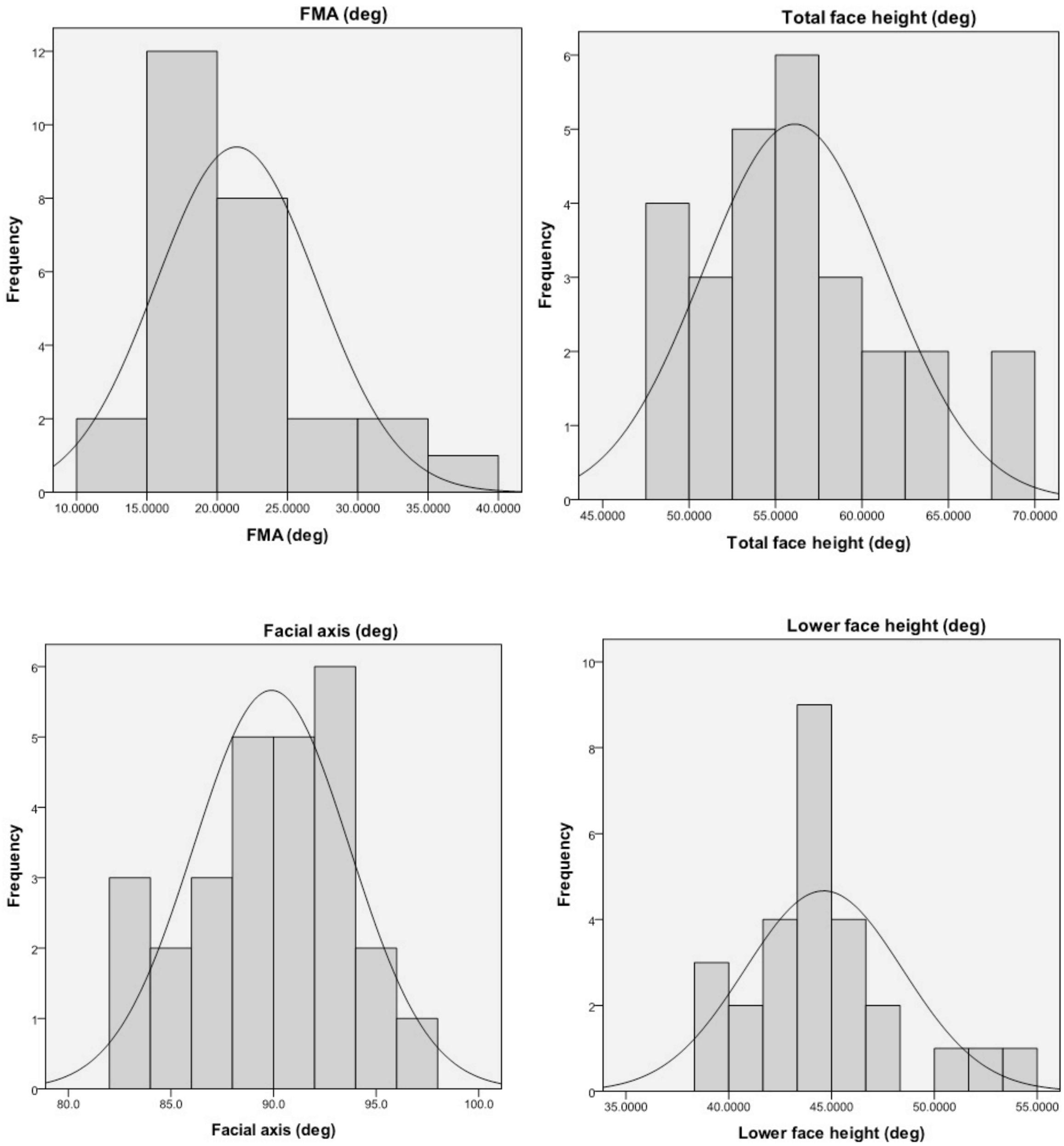


Figure 5: Continued

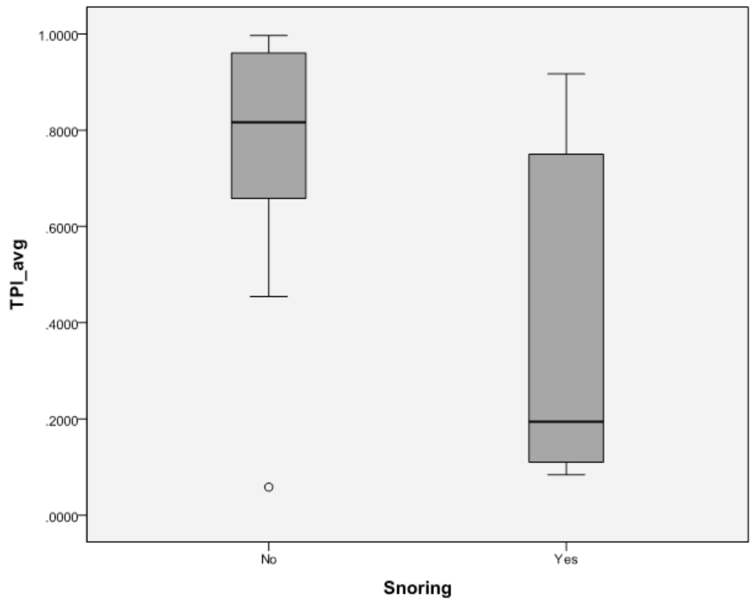


Figure 6: Self-reported Snoring (p = 0.037)

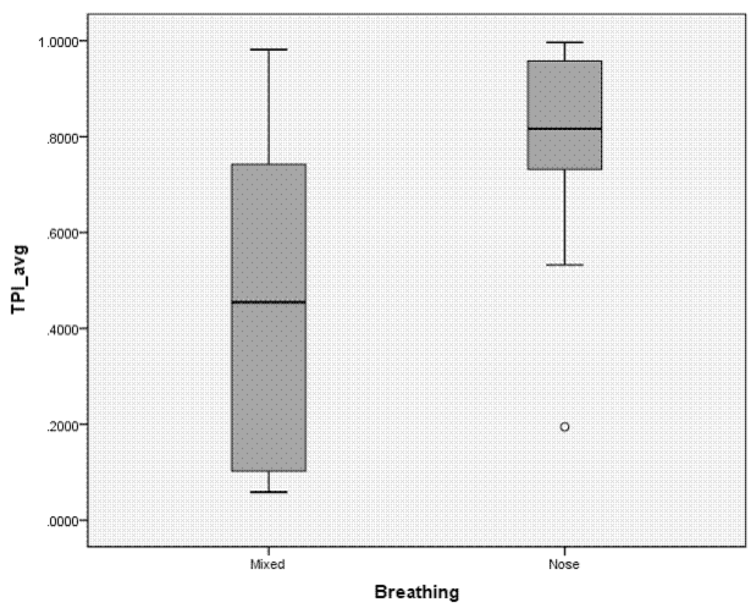


Figure 7: Self-reported Breathing Method (p = 0.057)

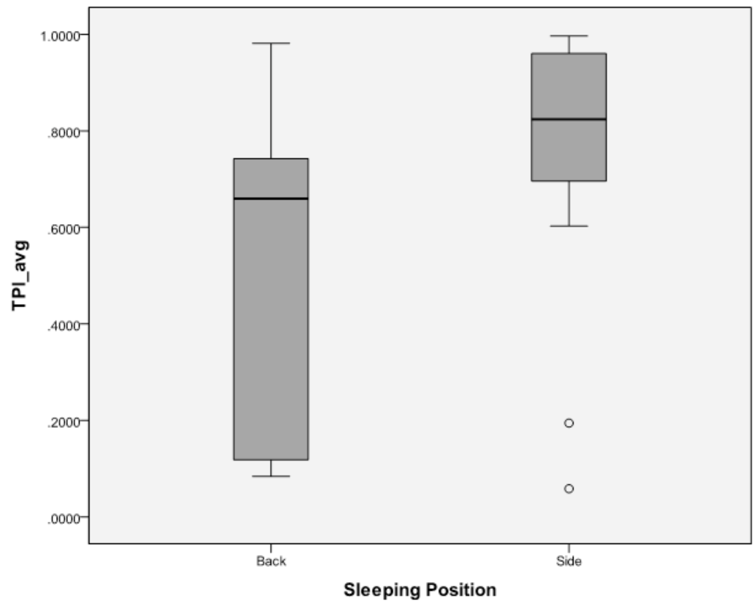


Figure 8: Self-reported Sleeping Position (p = 0.096)

Table 3: Non-Parametric Correlations (Spearman's Rho) of TPI with Independent Variables

	Correlation Coefficient	Significance (2-tailed)
Palatal Height	-0.575	0.002*
Palatal Width	0.341	0.081
Ratio Palatal Height/Width	-0.644	0.000*
FMA	-0.028	0.891
Lower Face Height	-0.423	0.028*
Facial Axis	0.180	0.369
Total Face Height	-0.188	0.347

*Indicates statistical significance of p<0.05

Table 4: Prediction Model - Classification Table

Observed	Predicted		
	TPI < 0.75	TPI ≥ 0.75	Percentage Correct
TPI < 0.75	10	2	83.3
TPI ≥ 0.75	2	10	83.3
Overall Percentage			83.3

Table 5: Prediction Model - Variables in the Equation

							95% C.I. for EXP	
	B	S.E.	Wald	df	Sig.	Exp (B)	Lower	Upper
Sleep Position	3.581	1.623	4.867	1	0.027	35.924	1.491	865.554
Palatal Height	-0.905	0.374	5.854	1	0.016	0.404	.194	.842
Constant	15.833	6.978	5.148	1	0.023	7620018.404		

CHAPTER FIVE

DISCUSSION

Some of the findings from the collected data were intuitive. The subjects that exhibited low tongue posture had a significantly higher palate with a relatively narrower upper arch. This phenomenon is frequently observed in clinical situations where a patient has tongue thrust/posture issues or suffers from ankyloglossia. That subjects with recorded low tongue posture also had increased lower face height is not surprising either. However, one would think that mandibular plane, total face height, and facial axis would have been similarly related to tongue posture. While there was some correlation of TPI with total face height and facial axis, it was not statistically significant. The one commonality among the three statistically significant measurements is that they all involve the palate or maxilla.

Distribution

An interesting observation from the data collected is the distribution of average TPI values as seen graphically (Figure 5). The data does not follow a normal distribution but a bimodal skewed distribution which supports the notion that the most common tongue posture is with the tongue placed against the palate the majority of the time. Indeed, twenty of the twenty-seven subjects had an average TPI value that fell between 0.6 and 1.0 with twelve of those being above 0.8. Five subjects had an average TPI value of less than 0.2 while only two subjects fell in the range from 0.2 to 0.6. The significance of the bimodal skewed distribution would lead one to believe that we are looking at two different populations, one more prevalent than the other.

Variation in Tongue Posture

Several subjects demonstrated tongue posture patterns that might coincide with the different stages of sleep. For instance, Figure 9A shows the graph of one subject who on the first night had predominantly low tongue posture except for a period of nearly an hour, between 4:30am and 5:30am where the tongue was against the palate. On the second night a similar trend is observed in figure 9B with the tongue up for almost an hour from about 5:00am to 6:00am. To date, there are no studies that correlate tongue movement with sleep cycles but after studying the graphs of the 27 subjects used in this study, it is an area that may merit further research.

Figure 10A shows the graph of a subject that began sleeping with a tongue down posture but proceeded, around 1:00am, to exhibit tongue up posture with short, intermittent cycles of the tongue falling away from the palate throughout the rest of the night. On the other hand, some subjects exhibited tongue up posture throughout the night with little to no variance as is illustrated in Figure 10B. This particular subject had nearly identical graphs for nights two and three.

Gender Differences

There was considerable difference in variation of tongue posture when comparing male TPI scores with female (Figure 11). Though not statistically significant after adjusting for other significant covariates of TPI ($p = 0.098$), it is an interesting observation and might be an avenue for further study with increased sample size.

Study Improvements and New Directions

Increasing the sample size would be a major improvement to this study. Also, creation of a tongue-posture-monitoring device that was less intrusive would allow for daytime subconscious recording of tongue posture. The expensive components needed for a cordless device made it cost-prohibitive to pursue such a mouth piece due to the budgetary limits of this research project. However, with better sponsorship one could conceivably construct a minimally-intrusive device, record daytime subconscious tongue posture, and compare readings with nocturnal tongue posture.

Using the device from this study the possibility exists to observe the tongue posture of targeted groups of subjects. Future studies might include the analysis of tongue posture in patients who exhibit posterior lingual crossbite. It would also be interesting to take a large sample population who exhibit a vertical pattern of facial skeletal growth and observe tongue posture patterns. Possibly the most significant study would be to observe the tongue posture trends in subjects that suffer from obstructive sleep apnea.

Conclusions

1. Sleeping tongue posture appears to be a dichotomous categorization with people belonging to one of two populations: Majority tongue-up or majority tongue-down.
2. TPI and lower face height are significantly and inversely correlated.

3. TPI and palatal height are significantly and inversely correlated.
4. TPI and ratio of palatal height to palatal width are significantly and inversely correlated.
5. Sleeping tongue posture may influence or be influenced by sleeping position, breathing modality, or tendency to snore.

A

B

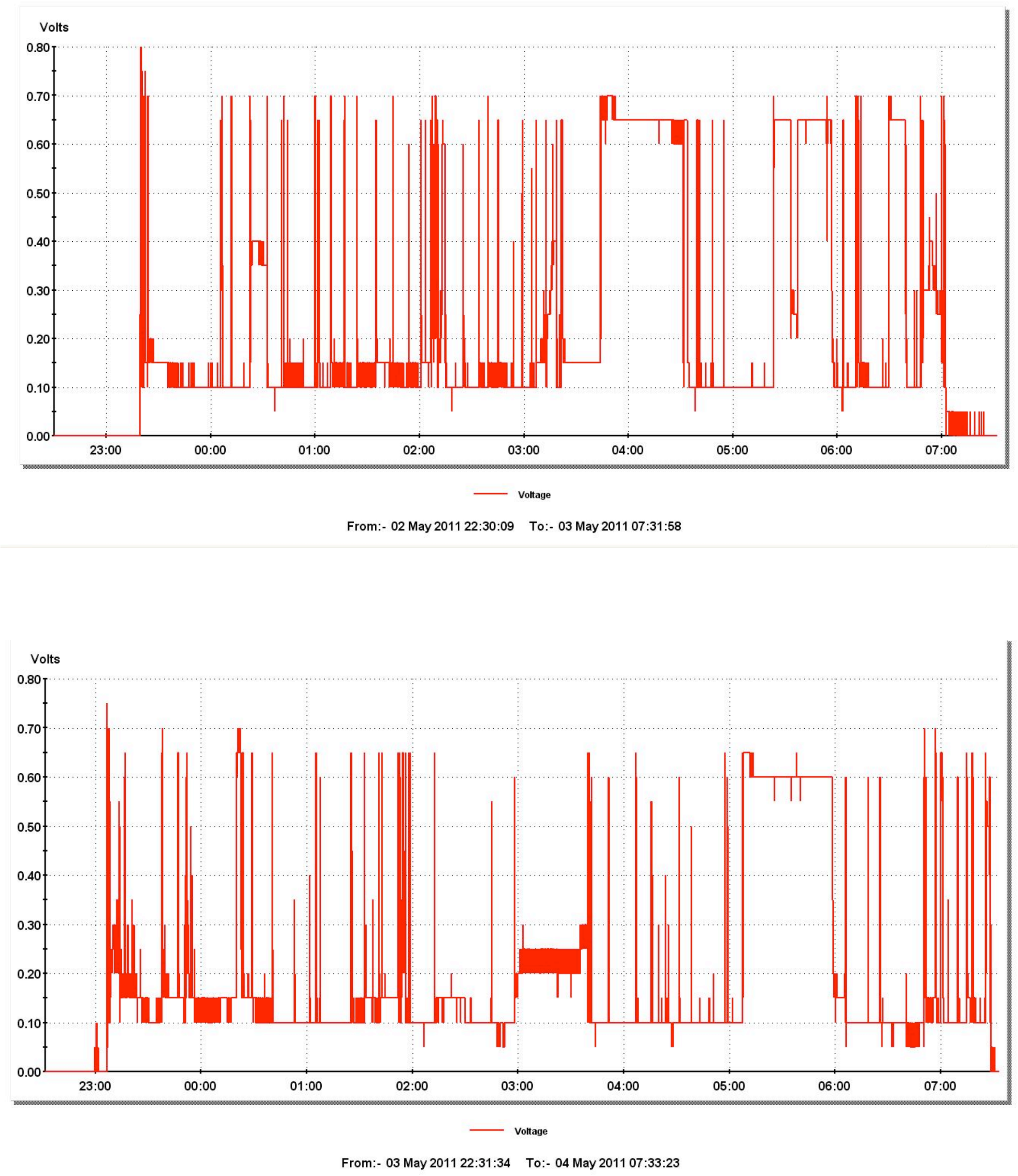
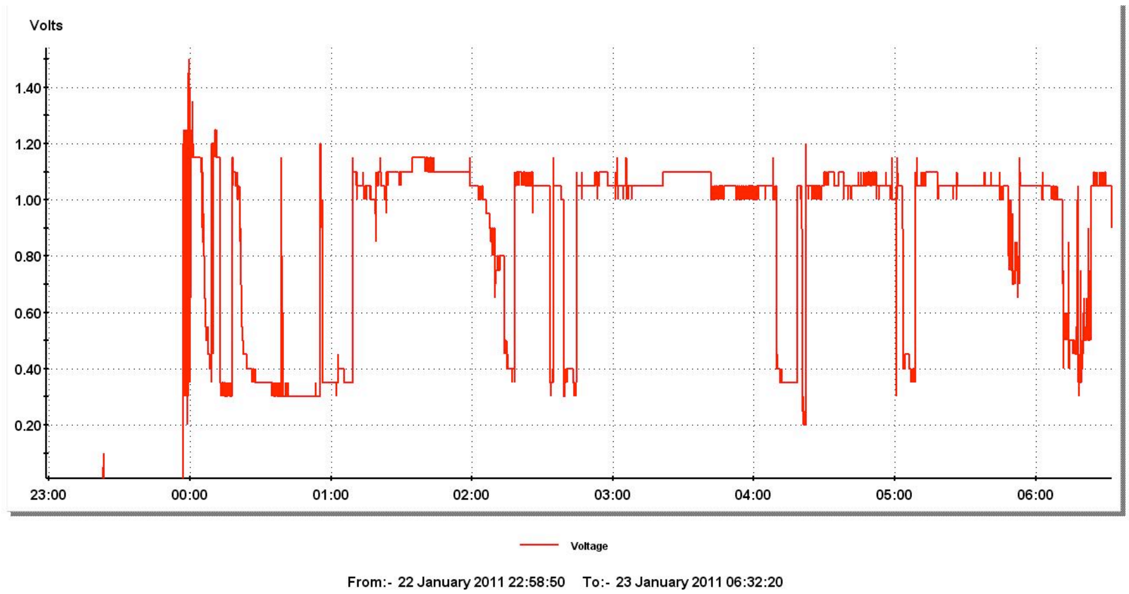


Figure 9. A: Graph of *night 1* of one subject exhibiting a short period of tongue-up posture between 3:00 am and 5:00 am B: Graph of *night 2* of the same subject with similar trend

A



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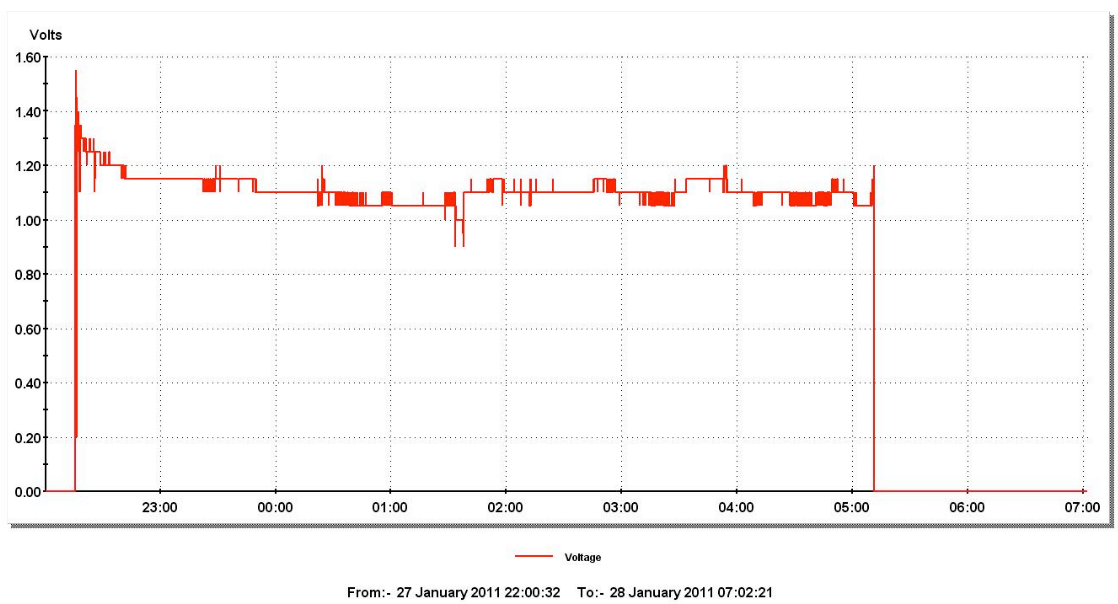

Figure 10. A: Graph of subject that exhibited variable tongue posture throughout the night
B: Graph of subject that exhibited only tongue-up posture for the entire night

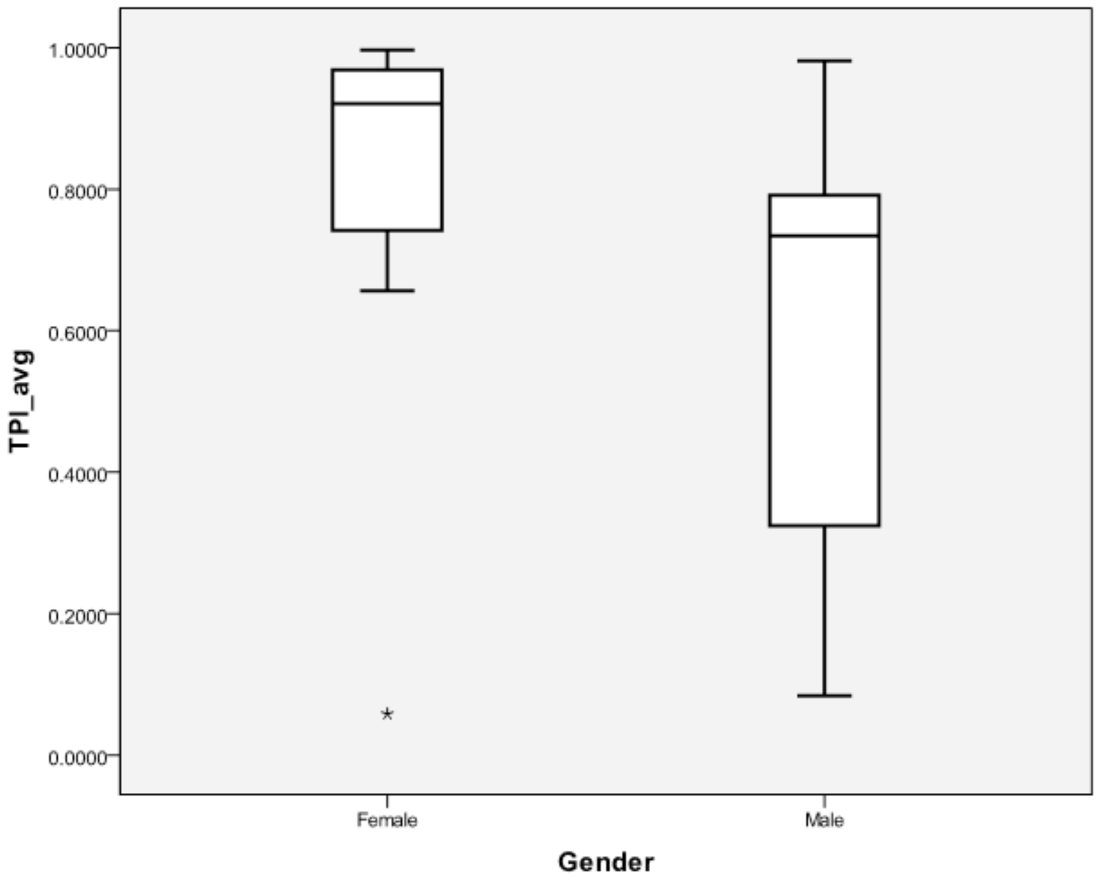

Figure 11: Comparison of average TPI scores between male and female subjects

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